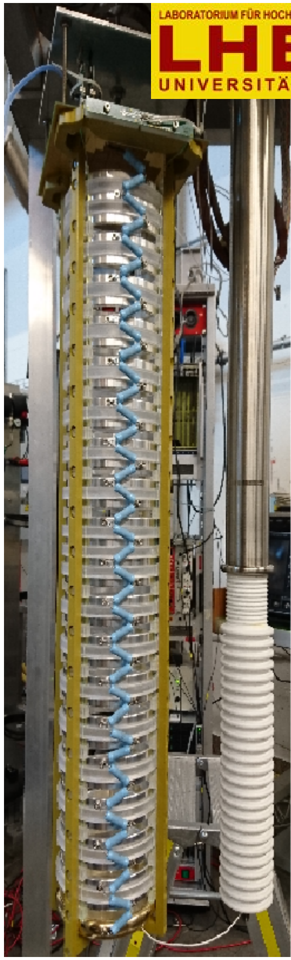
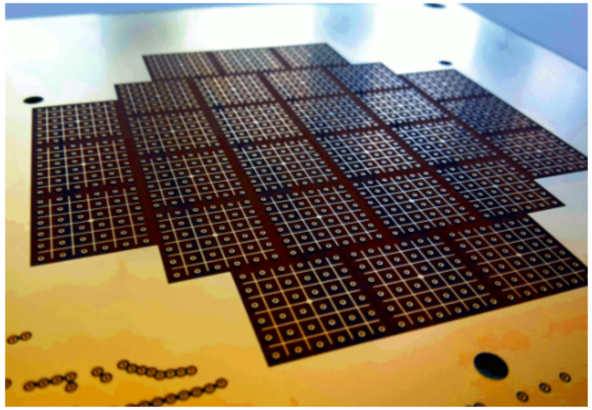
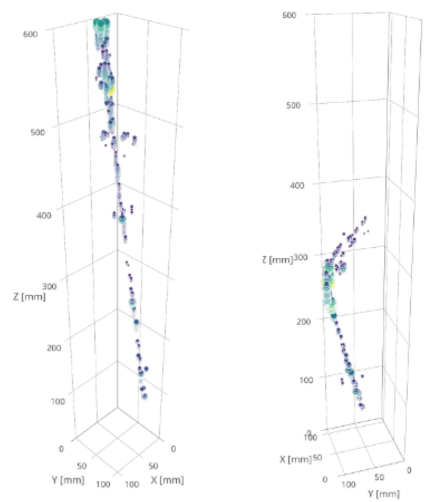
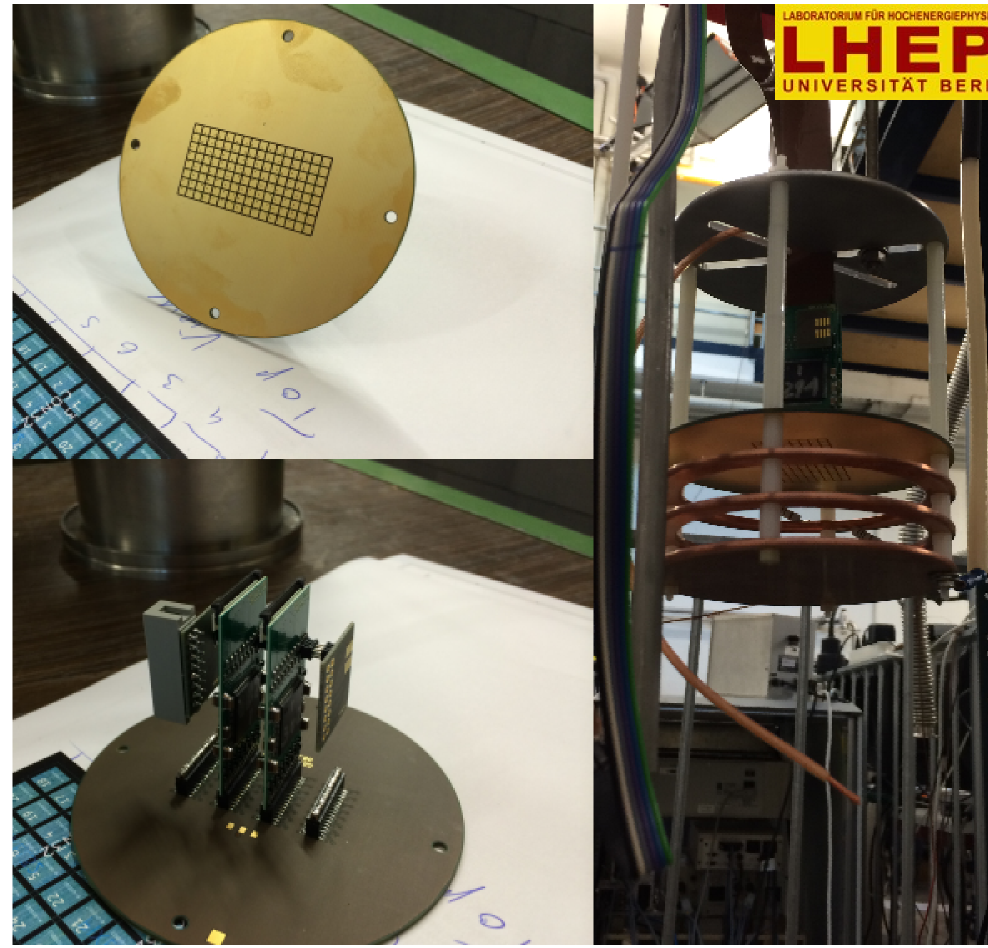
# Pixel Readout for DUNE



36 pixels per ROI, 28 ROIs, total 1008 pixels, 64 R/O channels, 3mm pitch, 600mm drift

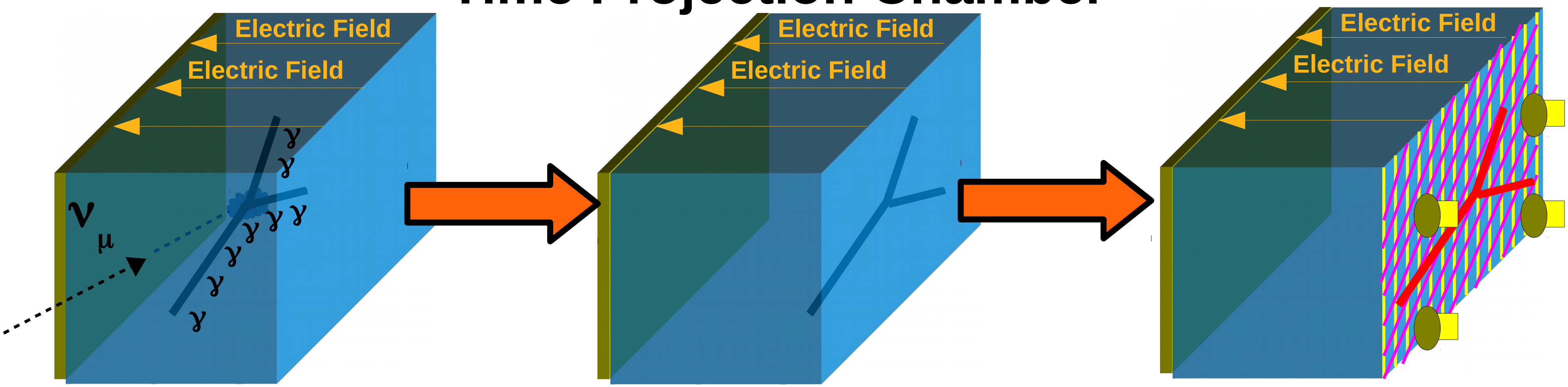



Jonathan Asaadi
UT Arlington

# LArTPC's

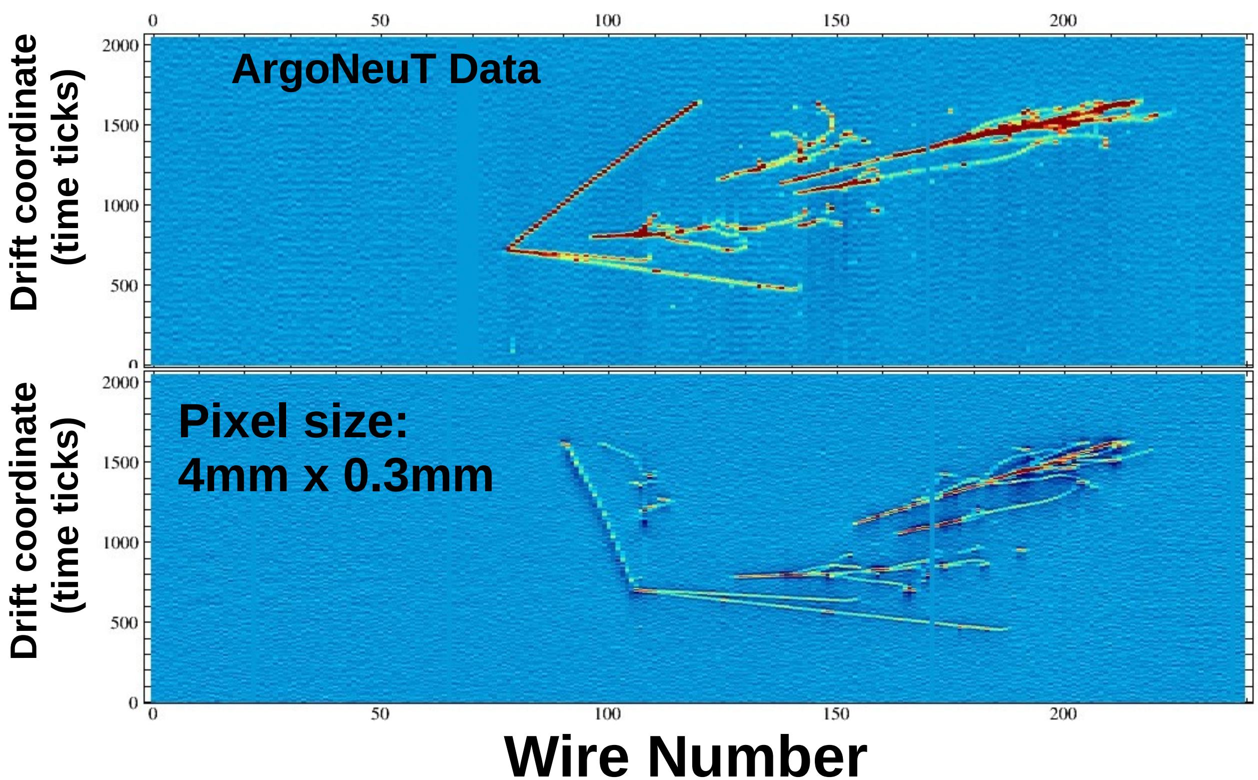
## Time Projection Chamber




Neutrino interaction in LAr produces ionization and scintillation light

Drift the ionization charge in a uniform electric field

Read out charge and light produced using precision wires and PMT's

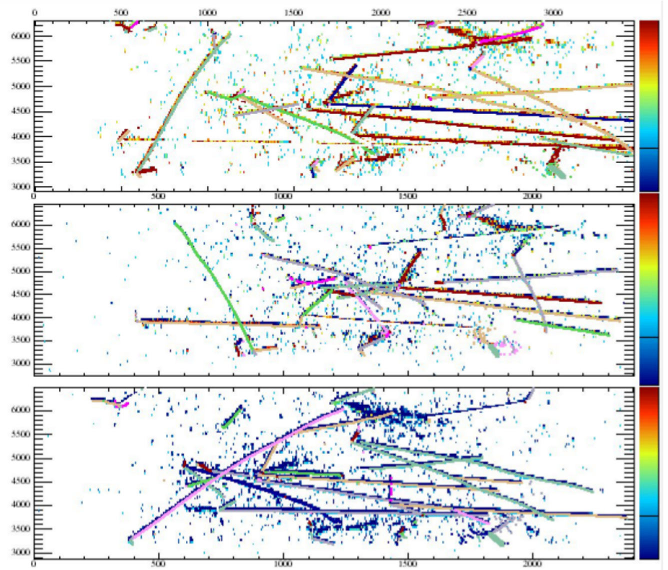



**LArTPC's offer incredible fine grain tracking along with electron/photon separation**

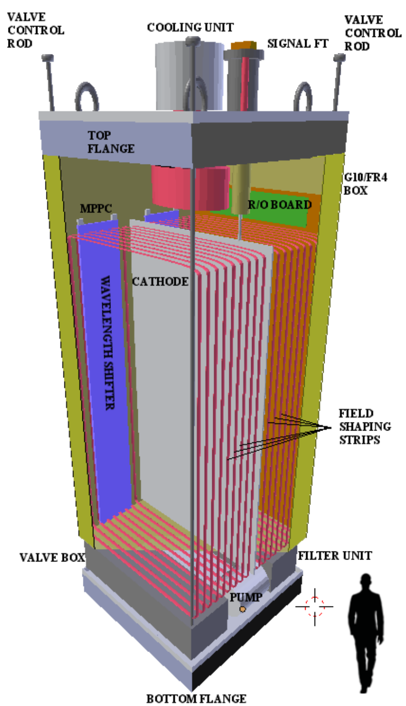
**However, wire based readout comes with some challenges**

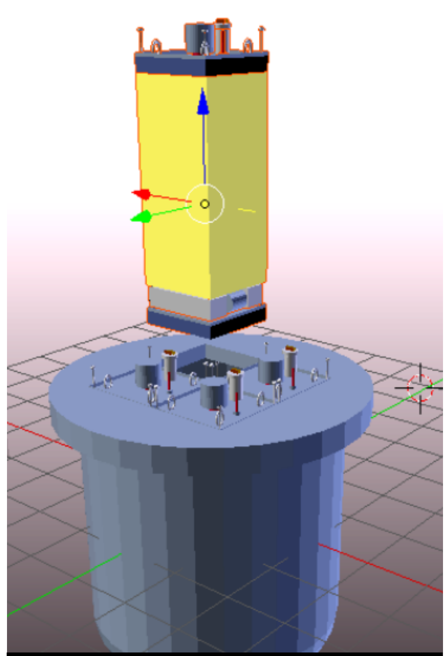
# LArTPC Challenges

- **One place where it would be advantageous to have a liquid argon neutrino detector is to serve as the DUNE near detector**
  - Target Nuclei the same between near/far
  - High density target (lots of statistics!)
  - Fine grain tracking and calorimetry broad energy range of neutrino cross-section measurements
- **However, this is a tough environment for a LArTPC!**
  - “Slow” drift time leads to large event pileup
  - High energy beam means high multiplicity events
    - Wire ambiguities are going to be present
- **A proposed solution is ArgonCube**
  - Modular LArTPC with short drift lengths (small drift times)
  - Accessibility to the TPC to allow for in-situ servicing and upgrades
  - Being designed with Pixel readout in mind
    - For more details about ArgonCube see a talk by J. Sinclair in another parallel session



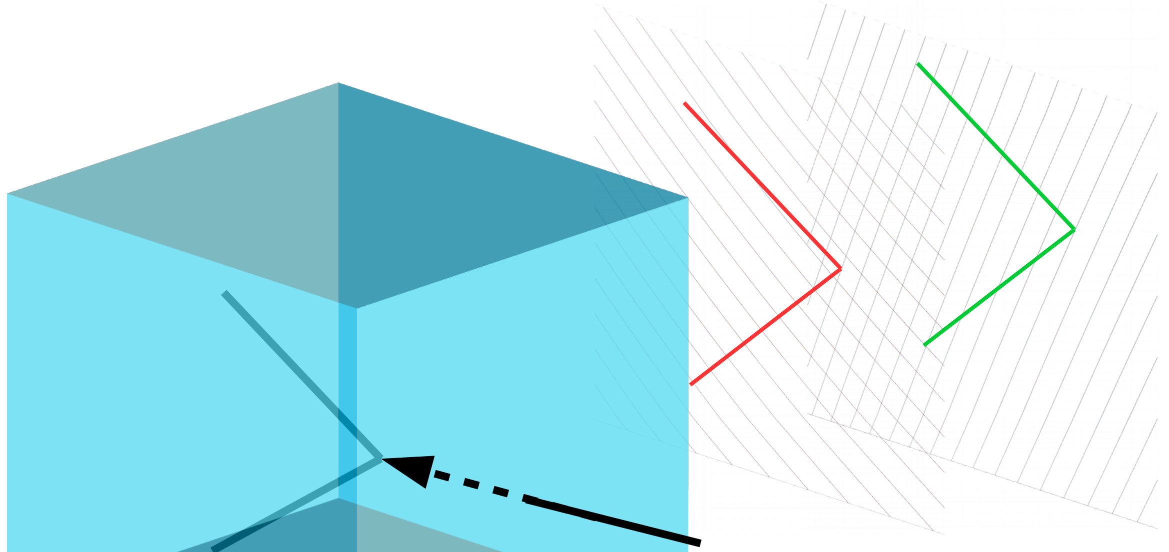
**MicroBooNE size detector in the DUNE Near Detector Beamline *(credit S. Lockwitz)***



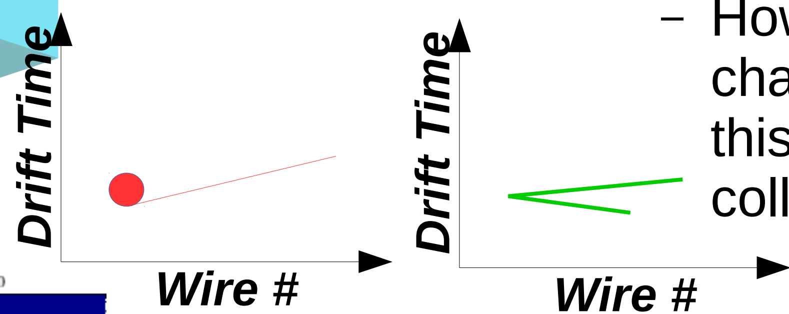



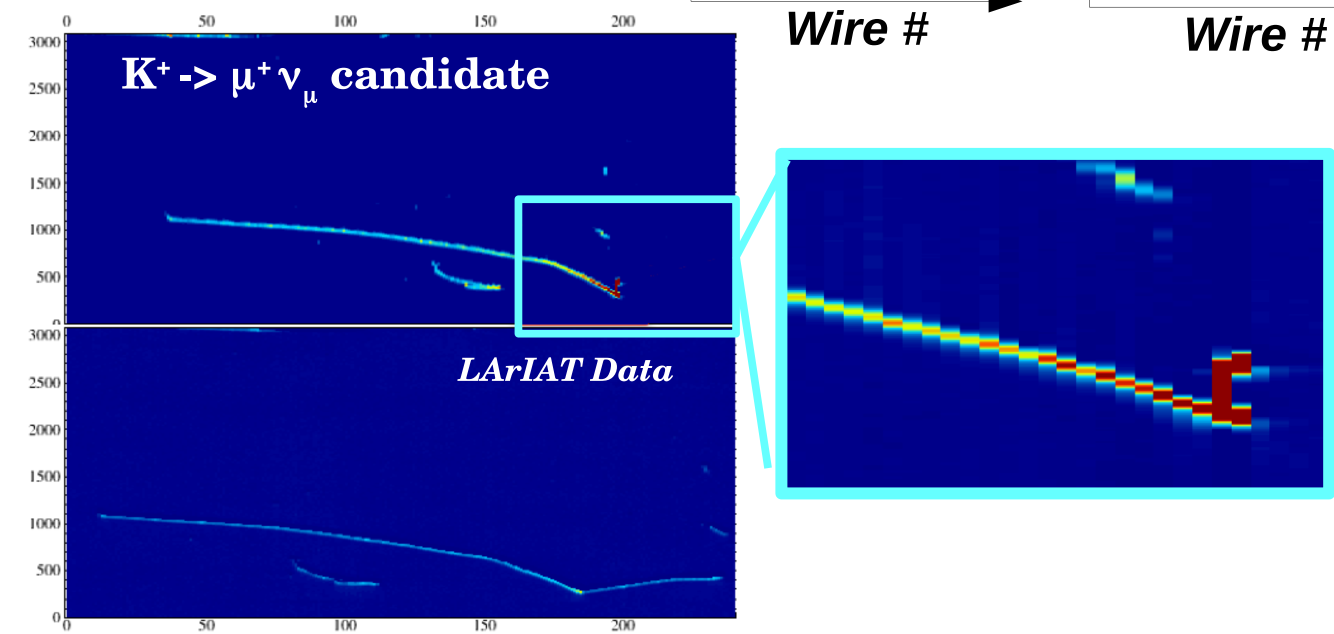
**0.6 m x 0.6 m x 1.8 m$^3$ ArgonCube Prototype**

# Why Pixel Readout?



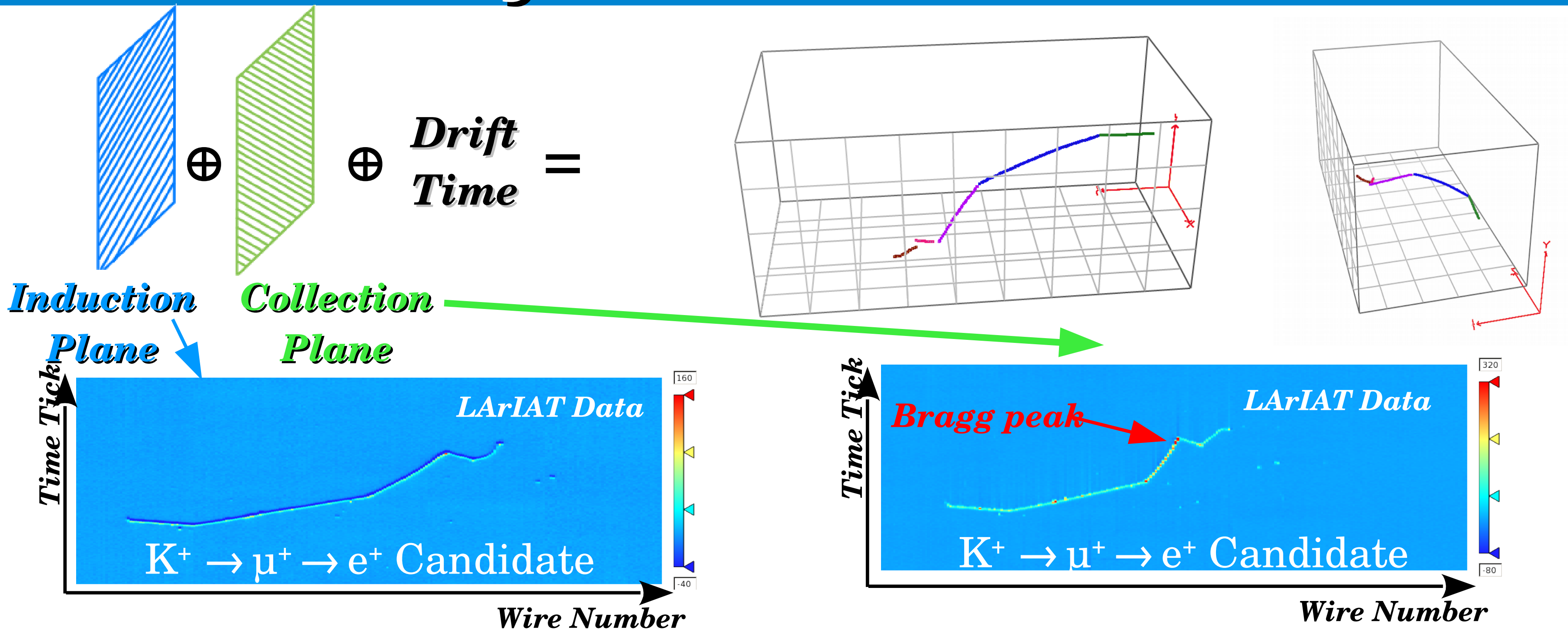
- **Ambiguities arrive when a track ionizes along the direction of one of your wire planes**
  - Appears as a “blob” of charge
- **Third wire plane helps break this ambiguity**
  - However, this can add challenges to the calorimetry if this happens to be your collection plane



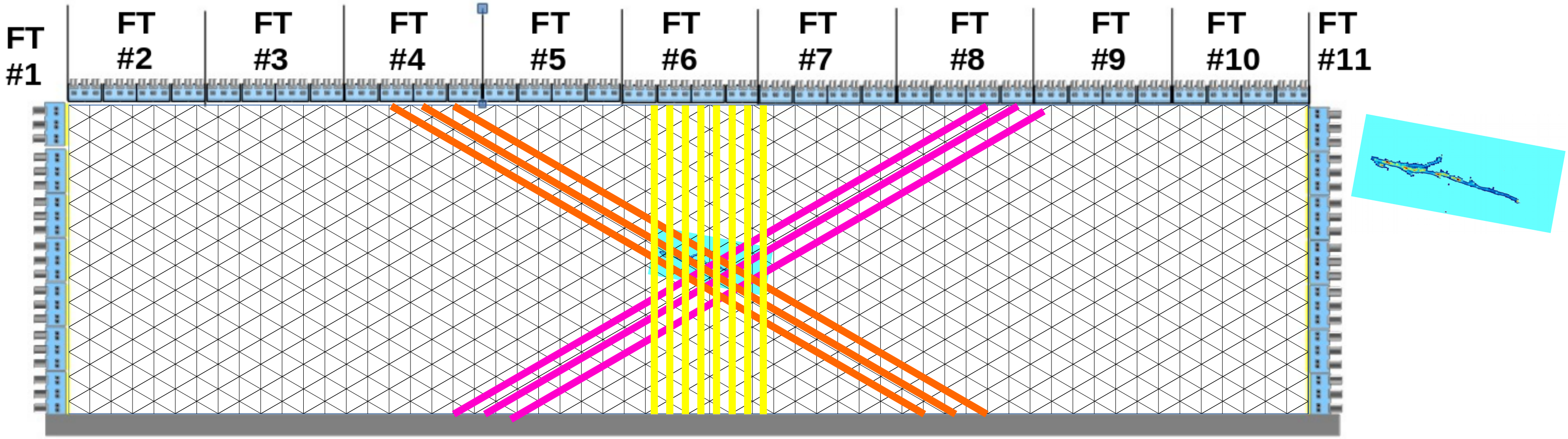

***Pixel style detectors don’t suffer from this same type of ambiguity***

# Why Pixel Readout?



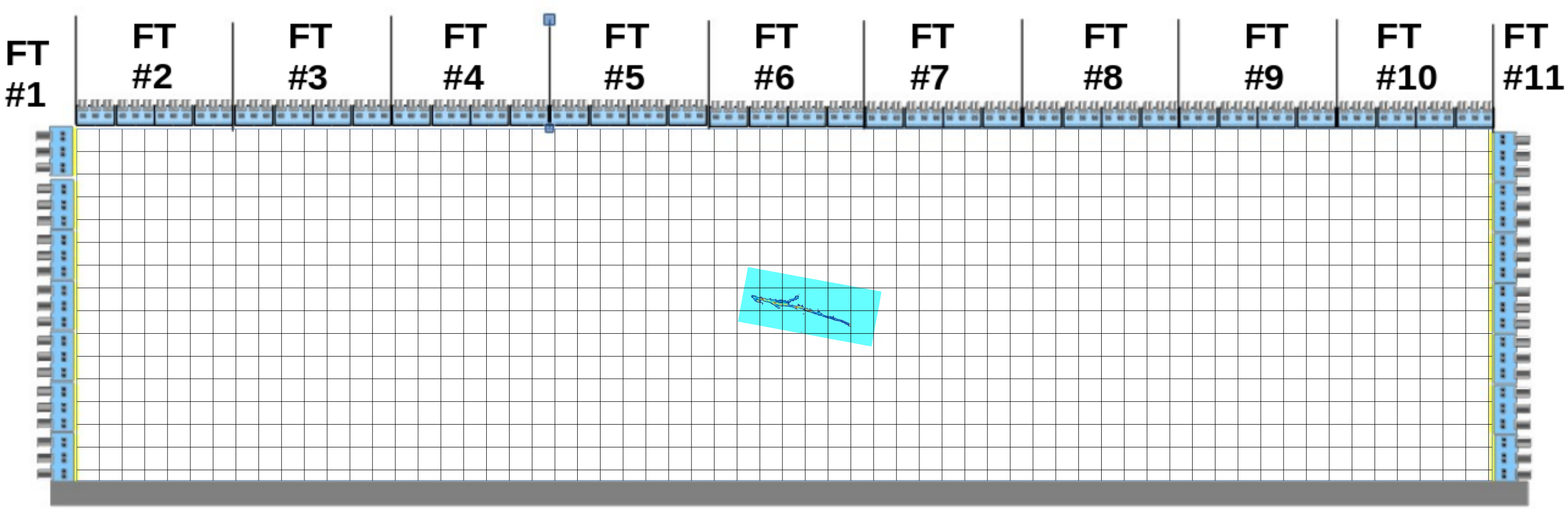

- **In order to do 3d reconstruction and calorimetry, wire readouts require you to bring together information from multiple wire planes to reconstruct the the event**
- **For rare event searches (supernova neutrino identification, proton decay, $n/\bar{n}$ oscillation searches, etc…) this requires quite a bit of "data wrangling"**
  - TPC signals from wires on different planes are readout meters apart, into separate crates, which then need to be assembled by an event builder before a decisions can be made
  - Ongoing work to find solutions is promising….but challenging

# Why Pixel Readout?

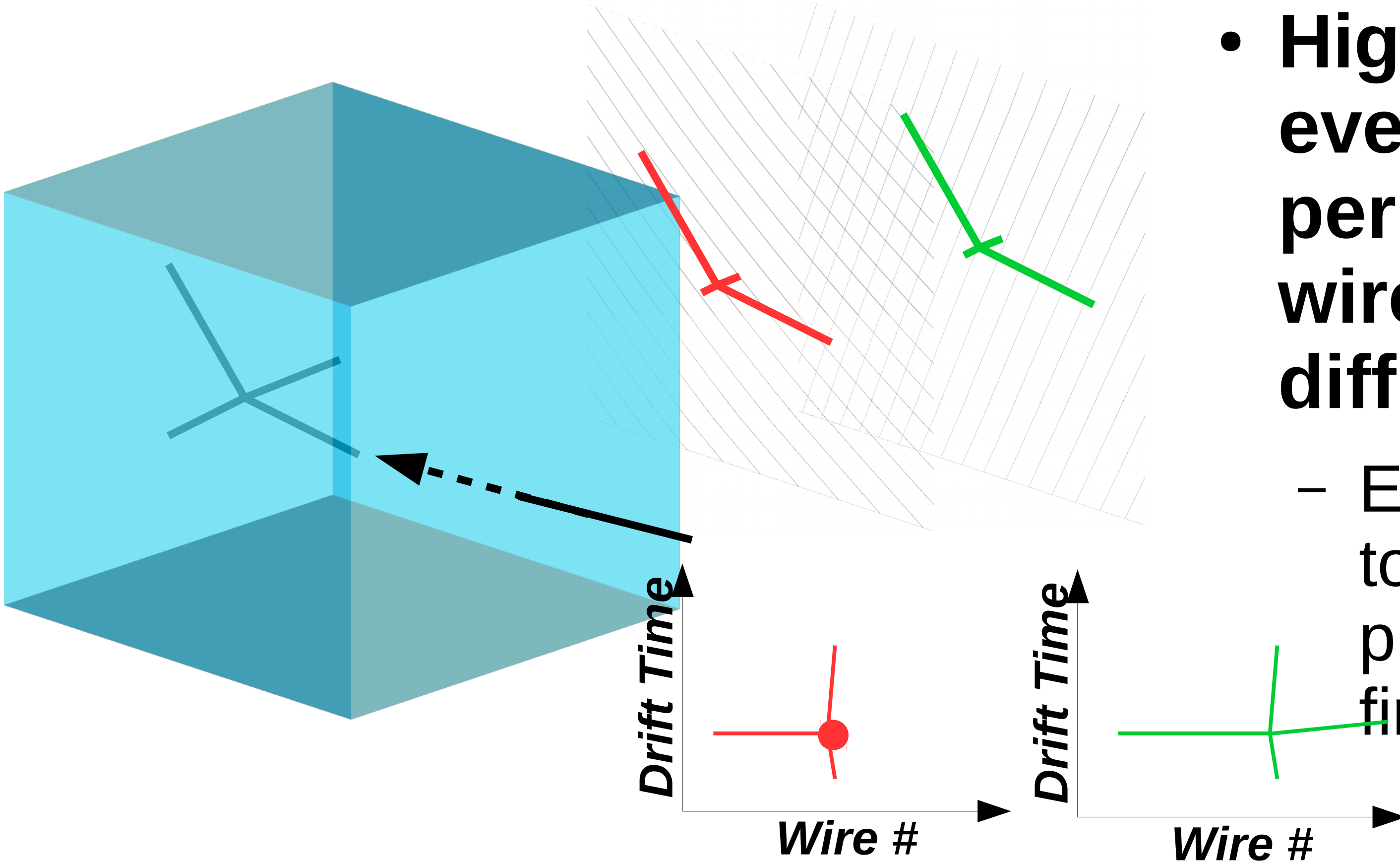



- **Imagine some low energy event in (ala supernova neutrino) where the activity is somewhere in your detector and small**
  - In a “MicroBooNE” size TPC, you need to gather together information across O(20) ASICS spread across O(10) motherboards which live on 3 different feedthroughs and that are routed to different racks/eventbuilders/etc….

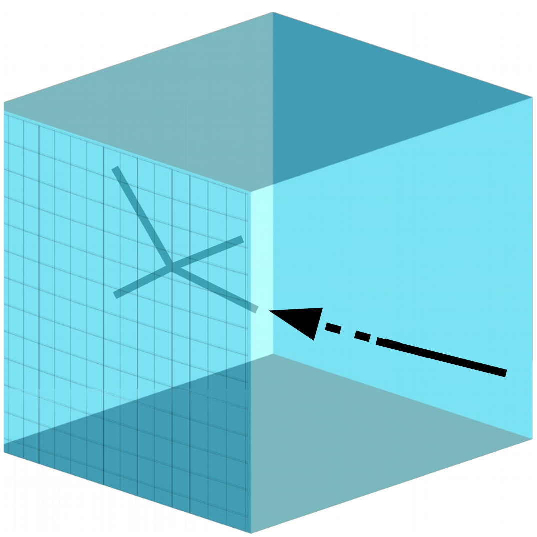
    Before you can say this is a an interesting event!
  - On a “pixel” version of the same detector….this could be done on O(1) chips!
  - Better yet….you could then send a warning out that something of interest has happened and the rest of the detector should readout too



# Why Pixel Readout?



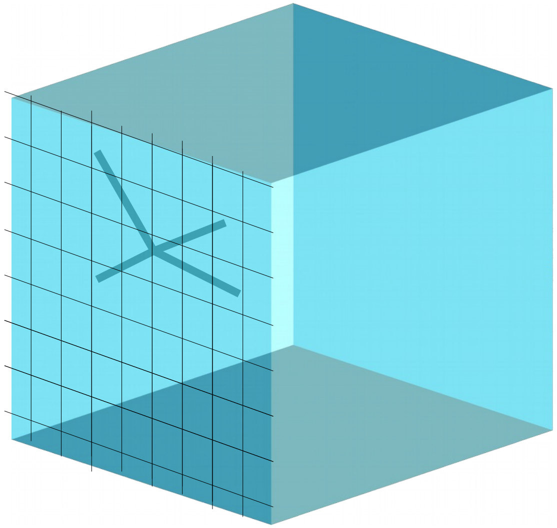

- **High multiplicity events with tracks perpendicular to the wire plane become difficult to disentangle**
  - Especially when trying to us the same charge pulse identification ("hit finding") algorithms

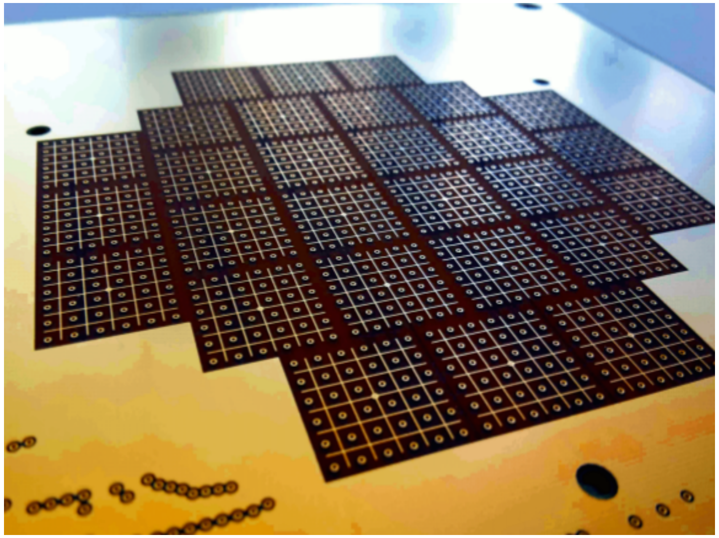


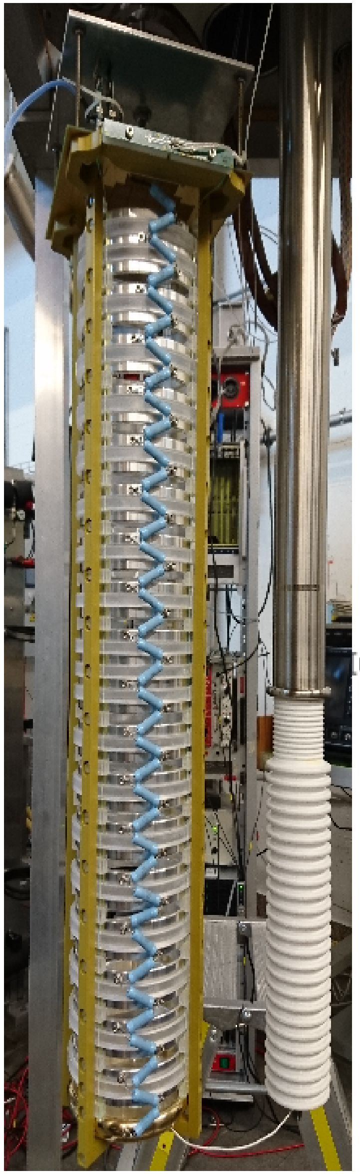
***By treating all pixel deposits at a given drift time the same, a pixel readout can avoid some of these challenges***

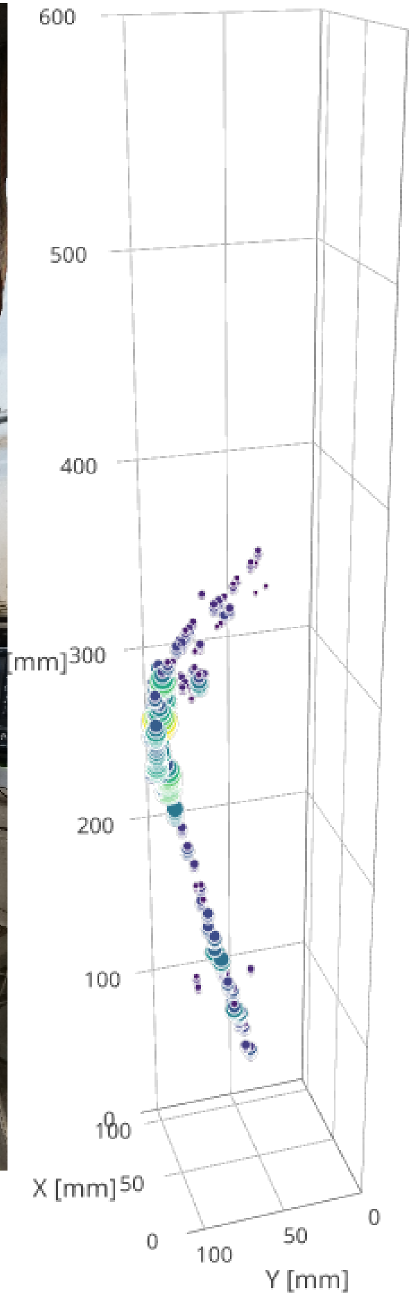
***(For sure, it will come with its own set of challenges...but might be a "better" battle)***

# Why Pixel Readout?







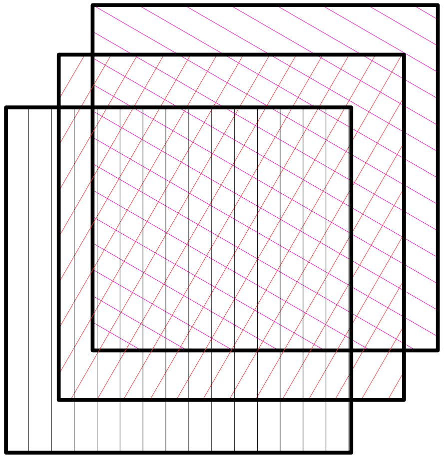



- **Pixel readout allows you to “go straight to 3d” with each readout**
- **Nearby pixels arrays can be analyzed by an FPGA to do rudimentary reconstruction and look for topologies of interest**
  - This claim obviously still needs to be demonstrated

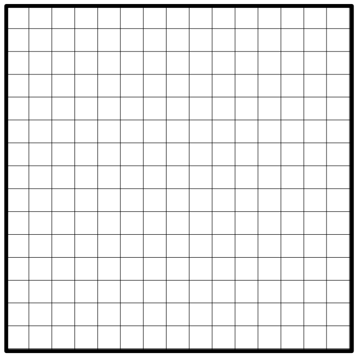
***See talk by J. Sinclair from Liquid Nobel Parallel session***

# What are the challenges?

- **Requires a large number of pixels to cover the entire area with the same separation as the wire pitch**
  - Example: 2 meter tall by 2 meter long volume w/ 3mm wire pitch
    - # of wires
      - ~650 collection plane wires
      - ~1800 induction plane wires
    - # of pixels
      - ~422,000 pixels

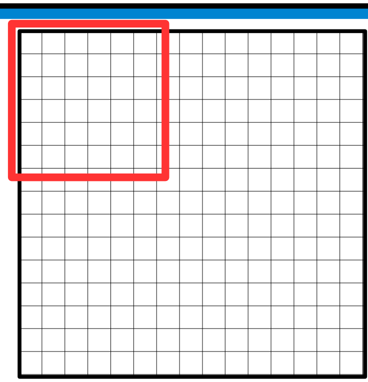


- **Large channel count requires new ideas in readout**
  - Can’t bring out every pixel as a channel!
  - Need to take power consumption of your electronics channel is the liquid argon into consideration



- **With the large channel count, heat loads due to the electronics start to become a concern**
  - The current analog front end ASIC (LARASIC4) is ~ 6-10 mW per channel
  - Current ADC ASIC ~200 mW per channel
    - Liquid Argon’s heat capacity 22.6 J/(mol K)
    - Liquid Argon has a liquid range of ~ 3 K

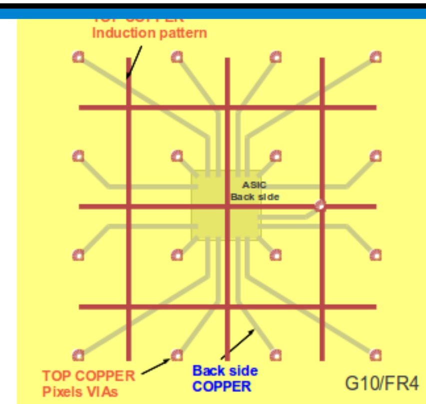
# Some ideas being worked on



A | B
---|---

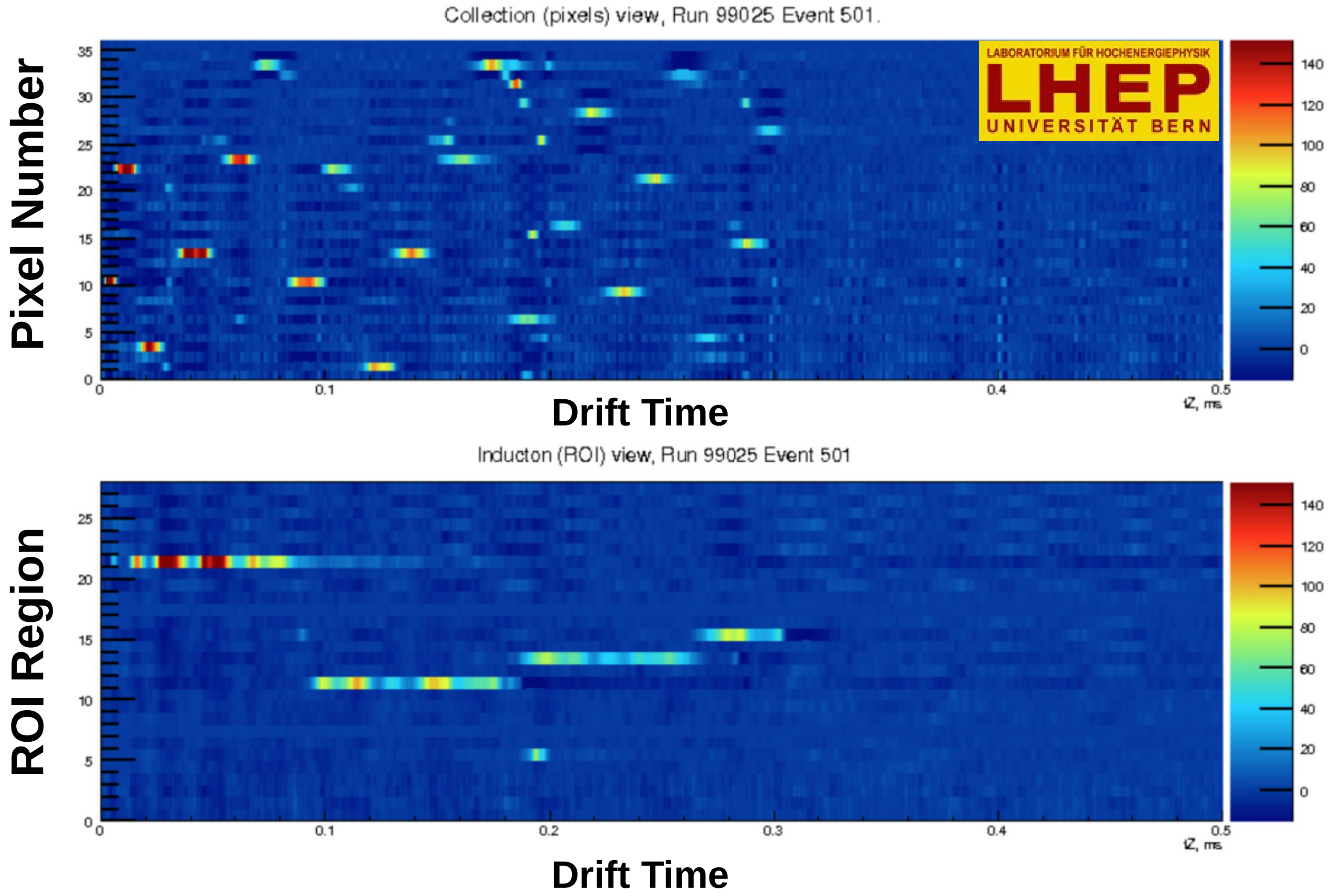
| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 1 | 2 | 3 |
| 4 | 5 | 6 | 4 | 5 | 6 |
| 7 | 8 | 9 | 7 | 8 | 9 |
| 1 | 2 | 3 | 1 | 2 | 3 |
| 4 | 5 | 6 | 4 | 5 | 6 |
| 7 | 8 | 9 | 7 | 8 | 9 |

C | D
---|---



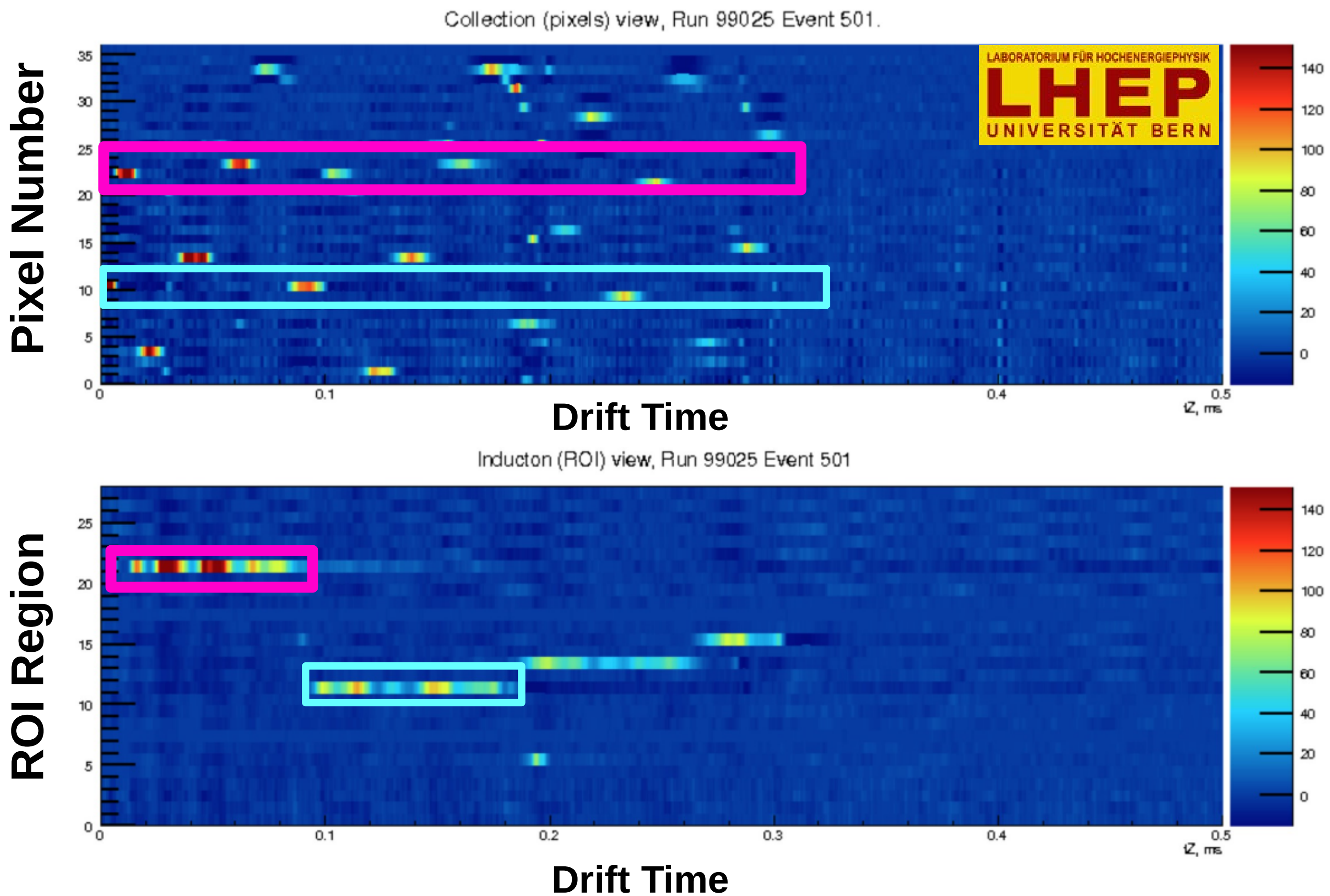

- **Using the existing front end ASIC you break up your channels by having Regions of Interest (ROI's A, B, C, D…) which are identified by an inductive trace and then you duplicate the same channel in each ROI (e.g. 1→9)**
- **Now one region can be readout by one 16 channel ASIC**
  - This allows you to readout your **N** pixels with **2 x sqrt(N)** DAQ channels (where N is the number of pixels)
    - How the current implementation of 1008 pixels is readout with 64 channels
    - Number of ASICS is just # of DAQ channels / 16
      - E.g. BERN Pixel TPC has just 4 ASICS

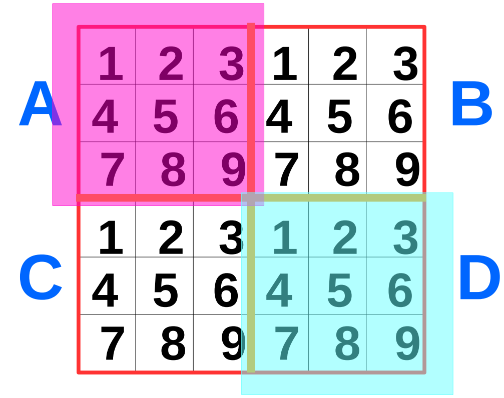
# Some ideas being worked on




- An idea currently being worked on is to take this approach and test it with a large number of pixels in a test beam envioronment
  - The Liquid Argon in A Testbeam (LArIAT) experiment is currently upgrading for a Run-III with ~600 channels available using the LARASIC4 chip

# Some ideas being worked on

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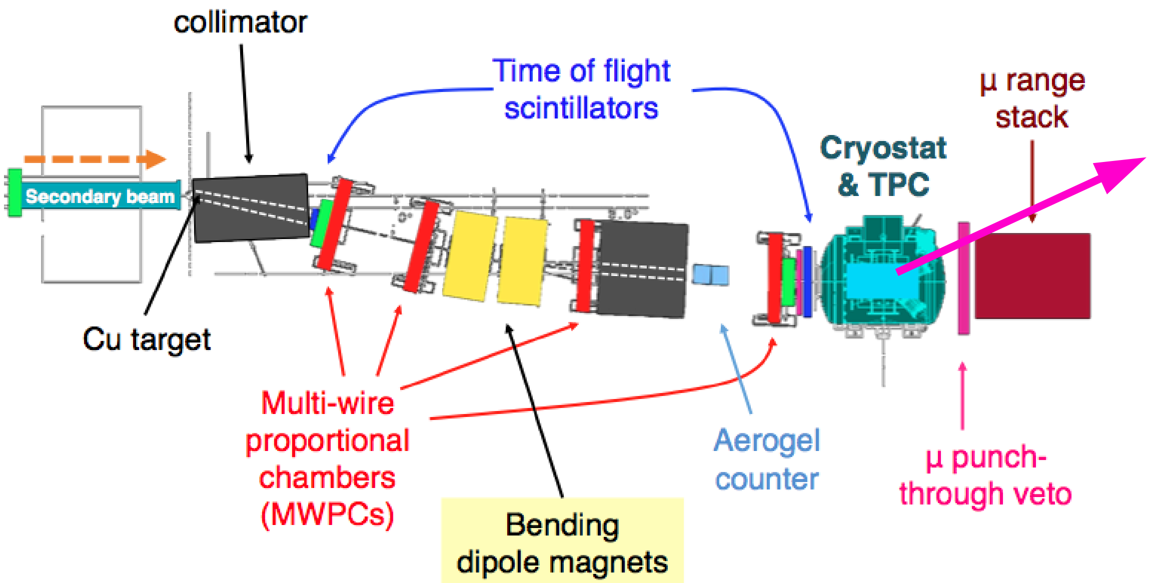
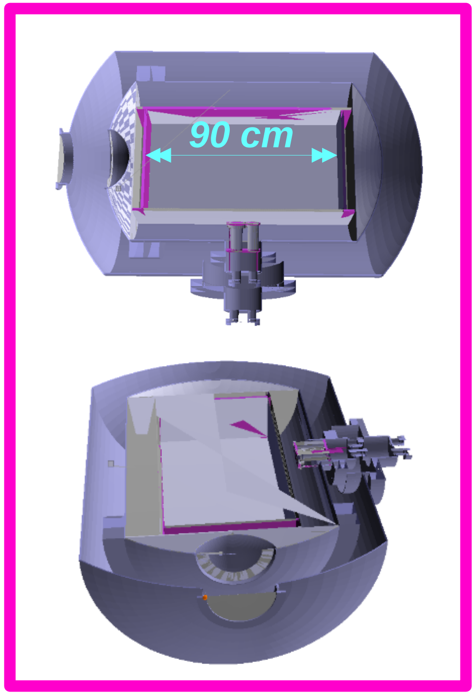
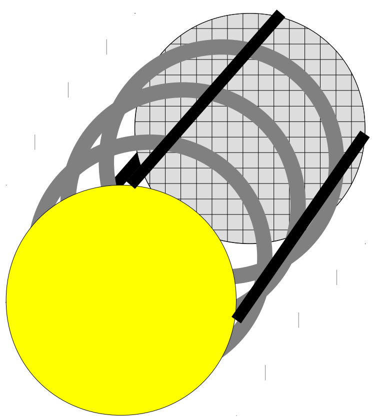
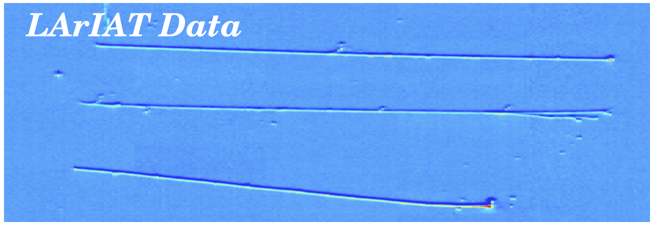
# Pixel Detector in LArIAT



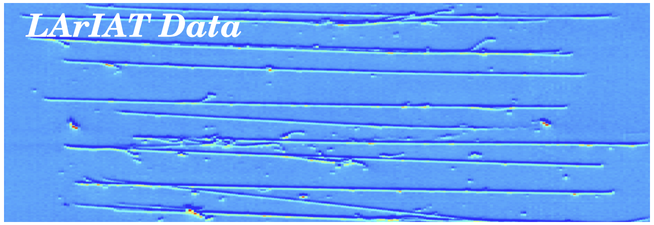



- **The idea would be to replace the existing TPC (90 cm x 47 cm x 40 cm) with a larger version of the Bern Pixel TPC with a large number of pixels readout in this ROI method**
  - For a ~45 cm diameter readout plane and 1.3 mm pitch that is ~92,000 pixels using all available channels
- **Can orient the TPC so the pixels are perpendicular and or parallel to the beam direction**
  - Longer drift if the pixels are perpendicular to the beam
  - Shorter drift if the pixels are parallel to the beam
- **The test beam is well understood and configurable to test high and low occupancy events**



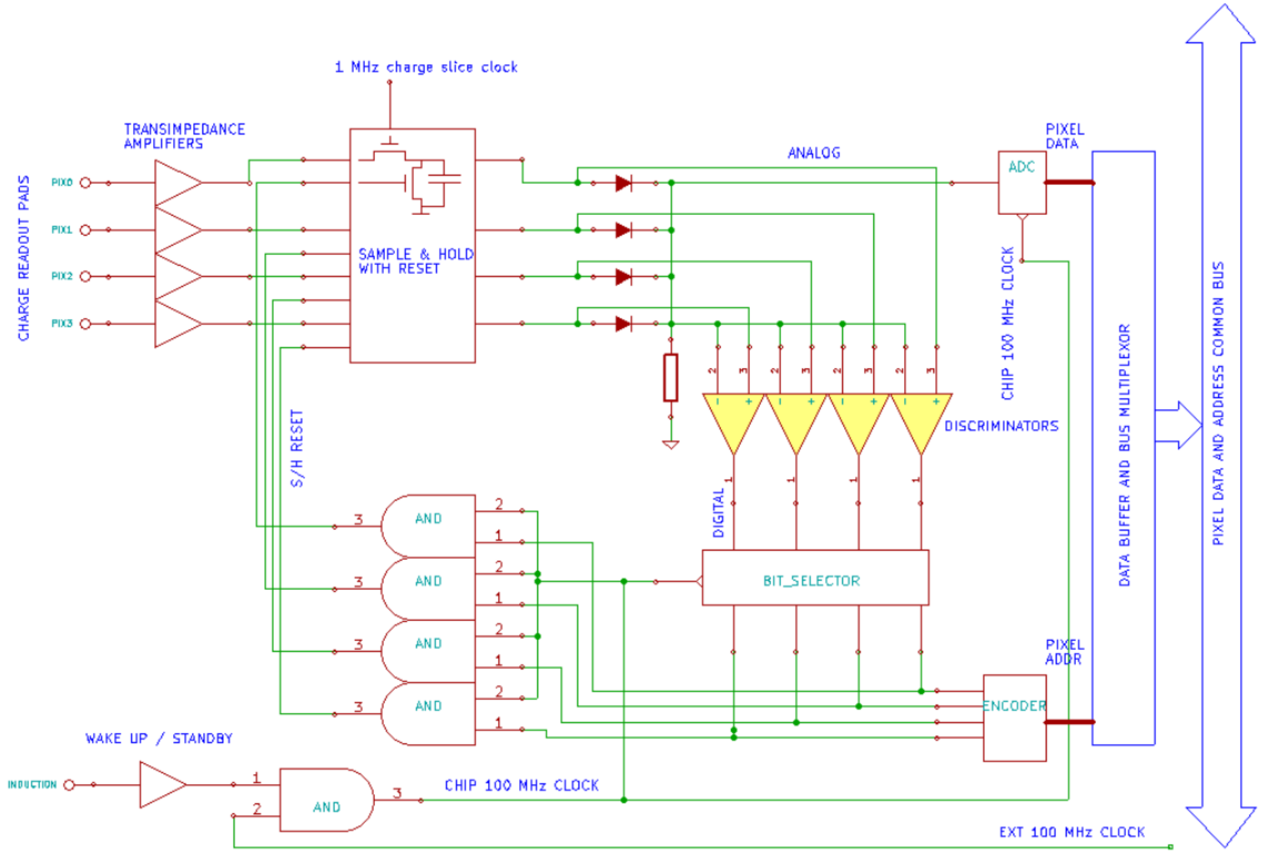

***Low Occupancy Beam Events***




***High Occupancy Beam Events***

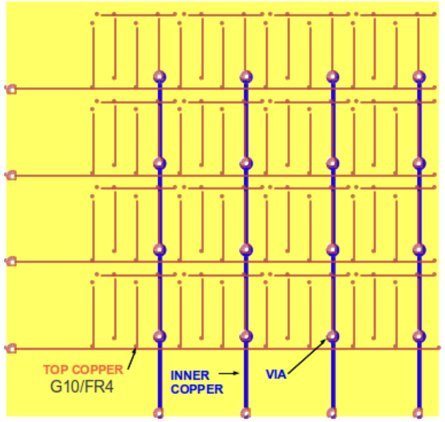
# Other ideas being worked on

- **Try to do a “smart token” zero suppression**
  - The readout is in a low power “sleep” state and is “woken” by the induction pulse
  - ADC could get a ~5μS “warning” from the induction signal
  - Use this to lower the power consumption

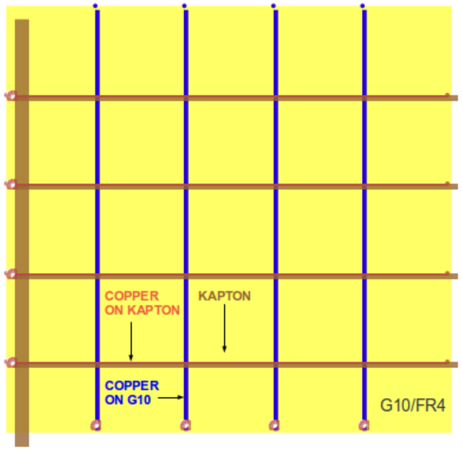



*Credit: I. Kreslo (Bern)*

# Other ideas being worked on




- **Currently using ASIC's designed for wire readout to do pixel readout**
  - Better being the enemy of the good….this is a good place to start
  - But we can do better

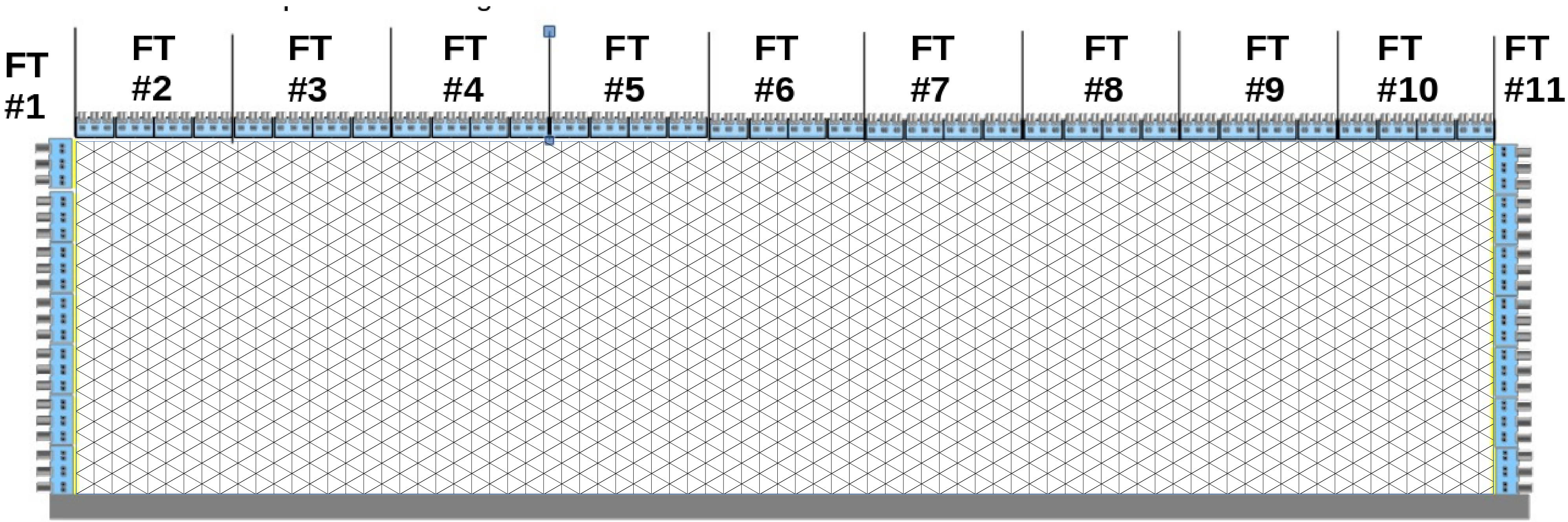



- **Looking forward to working with experts to think more about what is the "better" design for the electronics**
  - Next generation of LARASICS are in the pipeline….hopefully some possibility to test with those
- **Other pixel designs are being considered**
  - X/Y projection readout on PCV
  - Low capacitance Kapton on PCB X/Y Readout

# Conclusions

- **Liquid Argon TPC's provide an excellent neutrino detector technology**
  - However, the conventional wire readout provides challenges
    - Difficult to disentangle complex events
    - Requires putting together information from across the TPC to do 3-d reconstruction
      - Challenge for "triggering" on rare events
    - Not mentioned in this talk: Construction of large wire planes is non-trivial and single wire failure can cause "headaches" for your TPC
- **The pursuit of pixel based LArTPC provides an exciting opportunity to address these problems**
  - Work is ongoing (being lead by the Bern group) and showing preliminary potential!
  - Further R&D for both the electronics, pixel design, and readout needs to be pursued

# Backup Slides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